

A Case Study: Building a Web-Based Dietitian Expert System

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Abstract - *This paper presents the development of a TeleHealth system built using an open source web-based expert system framework called Tohu. The expert system works by providing individualized diet and health recommendations to users based on each user's responses to a simple auto-reporting questionnaire. A comparison is given between the development and features of this system and similar systems. A description of the system development illustrates how a complex web-based expert system can be easily constructed using open source tools such as JBoss Drools and Tohu. Following a depiction of how the system can be used, the paper concludes with a discussion of opportunities for future work.*

Keywords: Web-Based Expert System, Drools, Tohu, Rule-Based System, Health Assessment, Diet Assessment.

1 Introduction

This paper presents an open source behavior monitoring and modification system in which patients can self-report their measurements and receive personalized diet and exercise feedback. TeleHealth systems are an emerging method of delivering health services to patients using telecommunications (e.g. chat, web-based expert systems, and video consultations). TeleHealth systems have seen increased use as health tools in recent years and have been shown to perform quite well [1]. In the Journal of the American Medical Association (JAMA), researchers at the Weight Control and Diabetes Research Center at Brown Medical School reported that a system in which patients submitted a weekly weight loss diary via email lost significantly more weight than those only given weight loss information [2]. Further results from studies published by Haugen et al. [3] and Digenio et al. [1] prove that TeleHealth systems are valuable and effective tools for bringing health services to a larger population.

These so-called TeleHealth systems may be a part of the solution, for the Center for Disease Control states that, American society has become characterized by environments that promote increased food intake, non-healthy foods, and physical inactivity [4]. Furthermore, the Journal of the American Medical Association observed that 72% of American men and 64% of American women are overweight or obese [5]. Also, for American men, this figure is increasing as time goes on. Research has shown

that persons whose weight approaches levels classified as "overweight" or "obese," tend to increase their risks of diabetes, heart disease, cancer, and stroke [6]. Without more effective health aides, there could be a huge economic and medical impact as the population ages and starts to see the negative effect of this type of lifestyle.

The proposed TeleHealth system developed is called eDietitian; it leverages the Internet and existing tools to provide dietitian consultations to a larger population. The software performs a virtual consultation with the user by mimicking a consultation with a dietitian and asking the user a dynamic series of questions related to their lifestyle and habits. After the consultation, the user is given a customized list of recommended practices they should try to incorporate into their lifestyle to achieve and maintain a healthy lifestyle.

2 Related Works and Tools

This section describes tools that are similar to eDietitian; it also provides information about the tools used to build eDietitian.

2.1 Background Software and Tools

The eDietitian system is written in Drools [8] (see Figure 1), a Java Virtual Machine (JVM) rules engine and language. Drools provides a Java implementation of the Rete Algorithm for efficient pattern matching of facts with rules. It's similar to other rule engines such as CLIPS and Jess. The other major tool used is the Tohu [7] framework. The framework provides classes (see Figure 2) for constructing the question-and-answer tree and rendering the user interface via jQuery.

2.2 Related Systems

One of the systems that inspired eDietitian was WebMD's Personal Diet Evaluator [9]. The Personal Diet Evaluator's approach is a little different from eDietitian's but they share a similar questions-and-answer format. The big difference between the Personal Diet Evaluator (PDE) and eDietitian is that PDE is an Adobe Flash application while eDietitian is rendered with pure HTML. Also PDE is not as dynamic to the user's responses as eDietitian. eDietitian's screens react at a much more granular scale than PDE's.

Another system which bears a resemblance to eDietitian is the “Mozambican Diet Assessment Tool” [10]. It was developed by the Mozambican Ministry of Health as a quick way to measure the diet of rural and urban communities. Donald Rose et al describe how the system works as follows:

“The Mozambican Diet Assessment Tool (MDAT) is based on a simple, qualitative 24-hour recall of household food intake. The person in charge of food preparation in each household is asked to recall all foods eaten by household members at each meal and snack time in the previous 24 hours. Field personnel, usually the provincial nutritionists, then assign points to each food consumed, using a simple scoring system.”

The eDietitian system differs from the Mozambican Diet Assessment Tool because it takes a different route during the evaluation by inquiring about exercise and BMI rather than strictly measuring the amount of nutrients consumed. The goal of MDAT is different from eDietitian's - which is mostly the reinforcement of a healthy lifestyle - rather than nutrient assessment.

Denning et al developed BALANCE, a smart phone application which measures caloric expenditure using sensor and activity sensing technology [11]. Their system can predict how much time a person has spent sitting, walking, jogging, or cycling each day and can recommend serving size to the patient to keep their caloric intake in balance with their expenditures.

3 eDietitian Design and Architecture

This section describes how the eDietitian system was designed and constructed using the Tohu framework and Drools language to generate the web application.

3.1 Knowledge Base

The knowledge base for the system was built using a rule-based approach. The final system contained approximately 80 rules of varying complexity. Rules came from numerous sources, but the main sources for rules are US Government sources such as: PubMed Health from the U.S. National Library of Medicine [12], the “Dietary Guidelines for Americans” from the US Department of Agriculture [13], and the Center for Disease Control’s Obesity and Overweight website [14].

3.2 Architecture

3.2.1 Server-Side

Figure 1 (right) shows the server-side stack of the system. Everything runs in a Java Virtual Machine (JVM) instance. On top of the JVM, a Tomcat container serves the normal web files, but also runs a RESTful web-service called the Drools Execution Server. This service provides an interface to the Drools knowledge-base via XML.

3.2.2 Client-Side

The client-side of the system could essentially be any program that knows about the RESTful interface used by the Drools Execution Server. However, this project made use of the Tohu's jQuery library as shown in Figure 1 (left) for UI development. The Tohu project provides a JavaScript framework which can dynamically create the HTML and manipulate the Document Object Model (DOM) based on the responses given from the Server-Side. The Tohu JavaScript library uses the popular jQuery library for client-side scripting.

The big advantage of having the system run as a web application is how easily the UI can be easily changed using Cascading Style Sheets (CSS). The view can be easily modified using just style sheets; without any modification of the rules or logic classes.

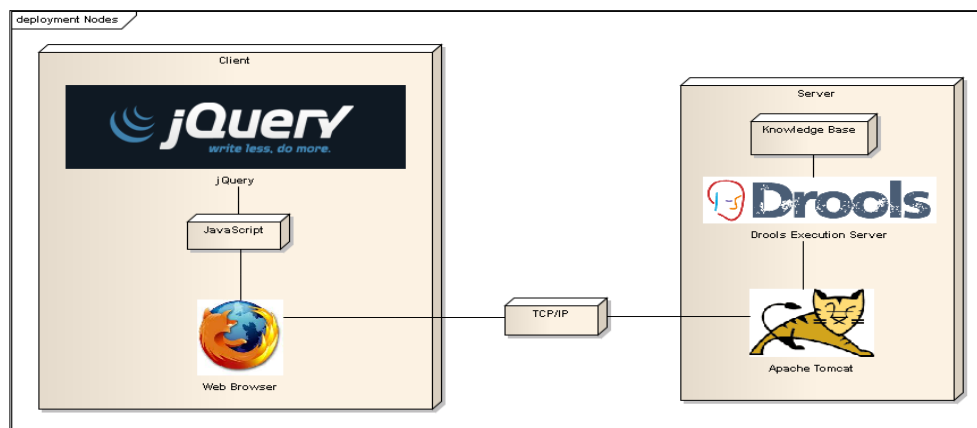


Figure 1 Client-Server stacks used in the eDietitian system. All components are open source.

3.3 Rule Workflow

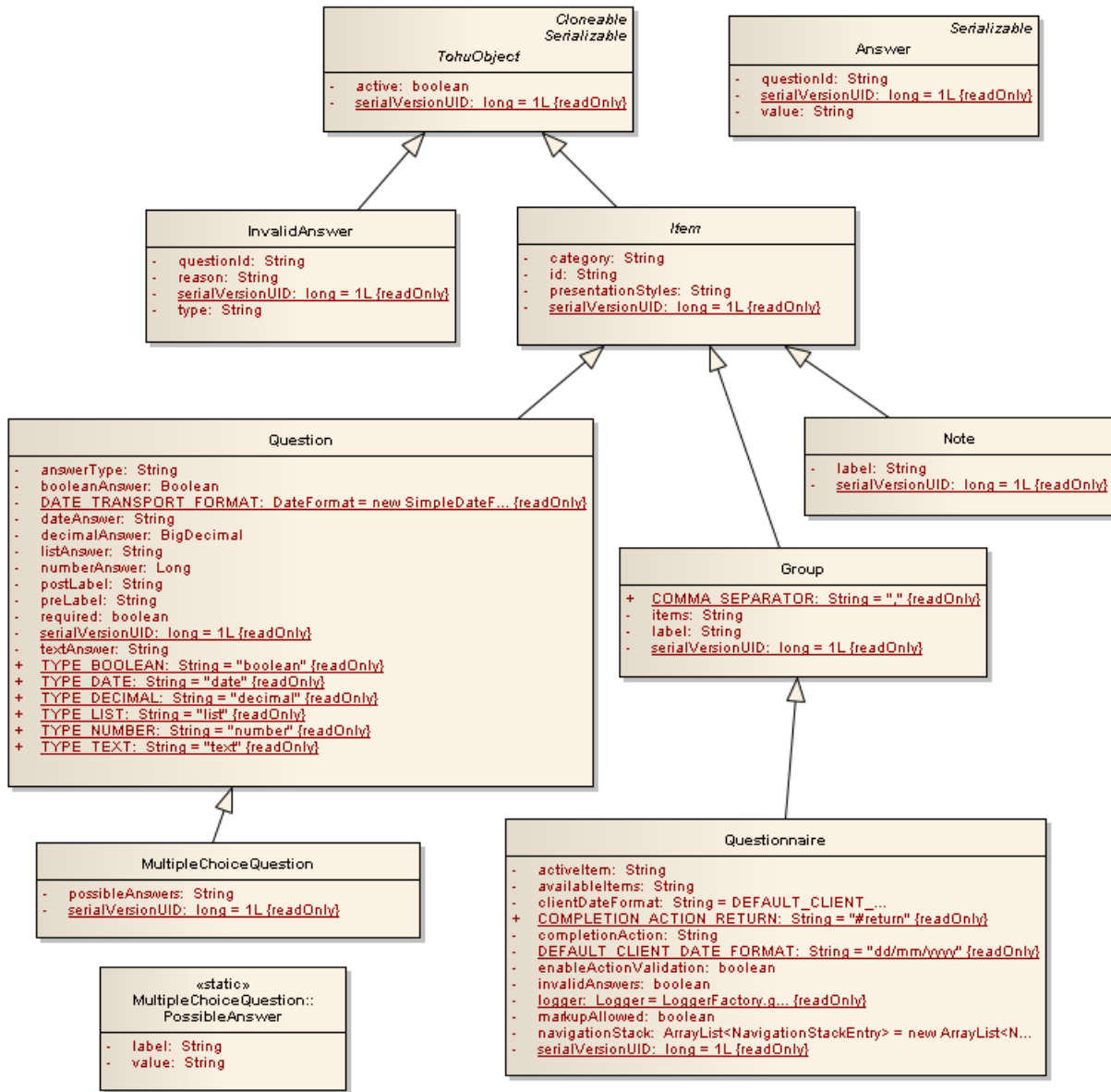


Figure 2 Class diagram of the Tohu core classes. These classes are used to build the decision tree.

The Java classes from Figure 2 are used to code the decision tree. A snippet of the Drools code is given to demonstrate this. Suppose we want to ask the user whether they exercise or not and provide a recommendation if they answer “no” to the question.

```

rule "ask if user exercises"
dialect "mvel"
then
    Question question = new Question("exercise");
    question.setAnswerType(Question.TYPE_BOOLEAN);
    question.setPreLabel("Do you exercise?");
    question.setPresentationStyles({"radio"});

```

Figure 3 shows the final screen with the recommendation at the bottom. Using the Tohu classes (Figure 2) to code the rule into the knowledge-base, we create a rule that inserts the Question object into the knowledge base as follows:

```

insertLogical(question);
. . . // similar code cut out for space
end

```

Please answer the following questions:

Do you exercise? Yes No

Do you smoke? Yes No

Do you drink? Yes No

You should exercise at least 2 hours per week.

Figure 3 How Tohu renders the above code with the recommendation at the bottom. A Boolean datatype is displayed as a radio button with Yes/No values.

Once the Question objects are in the knowledge base and some event changes their state, such as an Answer object being inserted into the knowledge base,

other rules that have them as an antecedent will fire which we can use to add yet more questions, facts, or recommendations into the knowledge base, for example:

```

rule "everyone should get at least 2 hours of exercise per week"
dialect "mvel"
when
  // if there is a Question with id==exercise and answer is false, then...
  Question(id == "exercise", answer == false);
then
  // display a note to the user that...
  insertLogical(
    new Note(
      "exerciseNote",
      "You should exercise at least 2 hours per week."
    )
  );
  // and give them a new exercise recommendation to be displayed on complete
  insertLogical(
    new ExerciseRecommendation(
      "needToStartExercising", // recommendation id
      Priority.HIGH,           // priority
      "You should start an exercise regiment.", // text to show
      new Source(             // link to source
        "http://www.cdc.gov/physicalactivity/everyone/guidelines/adults.html",
        "Physical Activity for Everyone: Guidelines: Adults"
      )
    )
  );
end

```

4 eDietitian Usage


The following section describes how eDietitian can be used, illustrated using screen-shots of the eDietitian system through various stages of the consultation session.

Once a user starts the questionnaire, he/she is asked some initial information, as shown in Figure 4, which is used to determine the user's Body Mass Index (BMI), Basal Metabolic Rate (BMR), and weight type (underweight, normal, overweight, obese). Next, the user

is presented with questions which gather information on exercise, as illustrated in Figure 5, and high-risk conditions including tobacco use and alcohol use. After this point in the conversation, the user's answers lead him to individually-determined questions based on their specific responses to the previous questions. This would mimic the way a doctor's consult would proceed – dynamically – from question to question. At the end of the session, the system displays the results of the questionnaire, and the user's exercise, eating and any other recommendations are displayed in a jQuery “accordion” widget, as depicted in Figure 6.

eDietitian Session

Tell me about your physical characteristics:



How tall are you? Height...

How much do you weigh? Weight...

Age Age...

Gender male female


Please note that questions **surrounded in red** are required questions.

[Next](#)

Figure 4 The initial screen of eDietitian gathers some initial information from the user.

eDietitian Session

Tell me more about your exercise:



How many days per week do you go to exercise? Days per week...

When you go to exercise, how many minutes do you stay for? Minutes per session...

When you exercise, do you typically: Typical exercise...

Do you bike or walk to work/school? Yes No

[Return](#)

Figure 5 eDietitian asks questions related to the user's exercise output (used to calculate BMR).

Results

Recommendations that you should try to follow

EXERCISE RECOMMENDATIONS

EATING RECOMMENDATIONS

- Consume less than 300 mg per day of dietary cholesterol, and limit your intake of animal products: milk, cheese, butter, etc. [↗](#)
- You should eat at least 5 servings of fruits or vegetables per day, each one having a different color.
- You should eat at least 3 times throughout the day. These are typically Breakfast, Lunch, and Dinner. However, it's better to eat smaller main meals with snacks in between, such as: Breakfast, Snack, Lunch, Snack, Dinner.
- Try to limit your intake of fried fast foods. [↗](#)
- You should consume 3190.0 calories per day because your exercise output is heavy. [↗](#)
- You should limit your daily sodium intake to 2300mg. [↗](#)
- You should keep a journal of what you eat and how many calories you consume.
- You are at an increased risk of Osteoporosis (loss of bone density). Get at least 1,200 milligrams per day of calcium and 800 - 1,000 international units of vitamin D3. Vitamin D helps your body absorb calcium. Your doctor may recommend a supplement to give you the calcium and vitamin D you need. Follow a diet that provides the proper amount of calcium, vitamin D, and protein. While this will not completely stop bone loss, it will guarantee that a supply of the materials the body uses to form and maintain bones is available. [↗](#)

OTHER RECOMMENDATIONS

Figure 6 eDietitian shows the results of the questionnaire, along with the user's exercise, eating and any other recommendations. The blue arrow at the end of each recommendation is a hyperlink to the source of the rule, and a "tooltip" shows the reference when the user hovers over it.

5 Review and Quality Assurance

One of the most vital issues that may impact the usability and successfulness of an expert system is the accuracy of the knowledge which it encodes. The knowledge base for the eDietitian system was based on trustworthy information from US Government sources, including the U.S. National Library of Medicine [12], the "Dietary Guidelines for Americans" from the US Department of Agriculture [13], and the Center for Disease Control's Obesity and Overweight website. Also, for review and quality assurance, a licensed dietitian was contracted to review the system. The review involved periodic live feedback sessions with the licensed dietitian, during which the developer and dietitian would go through the system screen-by-screen

and inspect the wording, flow, correctness, and usability of the system.

The review followed a cyclic model, where the developer would revise the system based on the dietitian's feedback, and then have another feedback session with the expert. Cyclic reviews were performed four times until the dietitian's feedback was fully incorporated.

6 Conclusions and Future Work

This paper presents the development of a TeleHealth system called eDietitian, a system built using an open source web-based expert system framework called Tohu. TeleHealth systems are an emerging method of delivering health services to patients and have been

shown to perform quite well [1]. The system uses a rule-based approach to provide individualized diet and health recommendations to users, based on completion of a simple auto-reporting questionnaire. A comparison was given between this system and similar systems. The architectural design and implementation were described, as well as usage of the system. This project demonstrates how a complex web-based expert system can be easily constructed using open source tools such as Tohu and Drools. eDietitian uses a web-based approach and leverages existing tools to make dietitian consultations more accessible to a larger audience.

Opportunities for future work include extending the system to allow for display of video resources and selections based on pictures. These enhancements would help make the questionnaire more user-friendly, and potentially increase system usability. In addition, the user interface can be refined by adding related pictures and video content that explain conditions clearly using rich content. Another potential path for future work is the addition of an explanation facility that could provide additional information to users about why certain recommendations were given.

7 References

- [1] Digenio AG, Mancuso JP, Gerber RA, Dvorak RV. Comparison of methods for delivering a lifestyle modification program for obese patients: a randomized trial. *Annals Internal Medicine*. 2009 Feb 17; 150(4):255-62. <http://www.ncbi.nlm.nih.gov/pubmed/19221377>
- [2] Tate DF, Wing RR, Winett RA. Using Internet technology to deliver a behavioral weight loss program. *Journal of the American Medical Association*. 2001 Mar 7; 285(9):1172-7. <http://www.ncbi.nlm.nih.gov/pubmed/11231746>
- [3] Haugen HA, Tran ZV, Wyatt HR, Barry MJ, Hill JO. Using TeleHealth to increase participation in weight maintenance programs. *Obesity (Silver Spring)*. 2007 Dec; 15(12):3067-77. Center for Human Nutrition, University of Colorado Health Sciences Center, Denver, Colorado, USA. <http://www.ncbi.nlm.nih.gov/pubmed/18198316>.
- [4] Center for Disease Control. "Obesity – At a Glance" <http://www.cdc.gov/chronicdisease/resources/publications/AAG/obesity.htm> as viewed September 2012
- [5] Katherine M. Flegal, Margaret D. Carroll, Cynthia L. Ogden, Lester R. Curtin. Prevalence and Trends in Obesity among US Adults, 1999-2008. *Journal of the American Medical Association*. 2010; 303(3):235-241. Published online January 13, 2010. doi: 10.1001/jama.2009.2014. <http://jama.ama-assn.org/content/303/3/235.full?ijkey=ijKHq6YbJn3Oo&keytype=ref&siteid=amajnl>
- [6] Obesity and Overweight for Professionals: Health Consequences. <http://www.cdc.gov/obesity/causes/health.html>
- [7] Tohu. <http://www.jboss.org/tohu> as viewed September 2012
- [8] Drools. <http://www.jboss.org/drools> as viewed September 2012
- [9] WebMD's Personal Diet Evaluator. <http://www.webmd.com/diet/diet-health-check/default.htm>
- [10] Donald Rose, Stephan Meershoek, Carina Ismael, and Margaret McEwan. Evaluation of a rapid field tool for assessing household diet quality in Mozambique. *Food and Nutrition Bulletin*, vol 23, No. 2. United Nations University Press. 2002. <http://archive.unu.edu/unupress/food/fnb23-2.pdf#page=65>
- [11] Tamara Denning, Adrienne Andrew, Rohit Chaudhri, Carl Hartung, Jonathan Lester, Gaetano Borriello, Glen Duncan. BALANCE: Towards a Usable Pervasive Wellness Application with Accurate Activity Inference. *HotMobile '09*. Proceedings of the 10th workshop on Mobile Computing Systems and Applications. *ACM*. New York, NY, USA 2009. doi:10.1145/1514411.1514416
- [12] <http://www.ncbi.nlm.nih.gov/pubmedhealth/> - PubMed Health, from the U.S. National Library of Medicine
- [13] Dietary Guidelines for Americans, 2010: <http://www.cnpp.usda.gov/Publications/DietaryGuidelines/2010/PolicyDoc/PolicyDoc.pdf>
- [14] <http://www.cdc.gov/obesity/index.html> – CDC's Obesity and Overweight main site